COFIRING COAL:FEEDLOT BIOMASS (CFB)and COAL:LITTER BIOMASS (CLB) in a B(R)OILER BURNER

PARTICIPANTS

Kalyan Annamalai , Prof, Mech.Engineering, Texas A&M

Dr. John Sweeten, Resident Director, Texas Ag. Ext. Center, Amarillo, TX

Sayeed Mukhtar, Asst. Prof., Agricultural Engineering, Texas A&M

Duration: 2000- 2002

DOE Biomass Meeting, NETL-Pittsburgh, Oct, 24, 2000

Students on Project

- **Mr Ben Thien, PhD Student (Experiments)**
- **Mr Geng Sheng Wei, PhD Student (Numerical Modeling)**
- **Mr Scott Carrel, MS Student (supported from other ongoing Programs)**

Background of Participants

- **Kalyan Annamalai: More than 25 years of research on coal combustion and 15 years on feedlot biomass gasification and combustion; current program will supplement 2 other ongoing programs on Cofiring Coal:FB in Boiler burner**
- **John Sweeten: Extension service specialist over 30 years of experience on feedlot waste management and worked with KA over 15 years**
- **Sayeed Mukhtar: Poultry waste management specialist; current program will supplement "Odors and Arsenic Emissions from Polultry Operations**

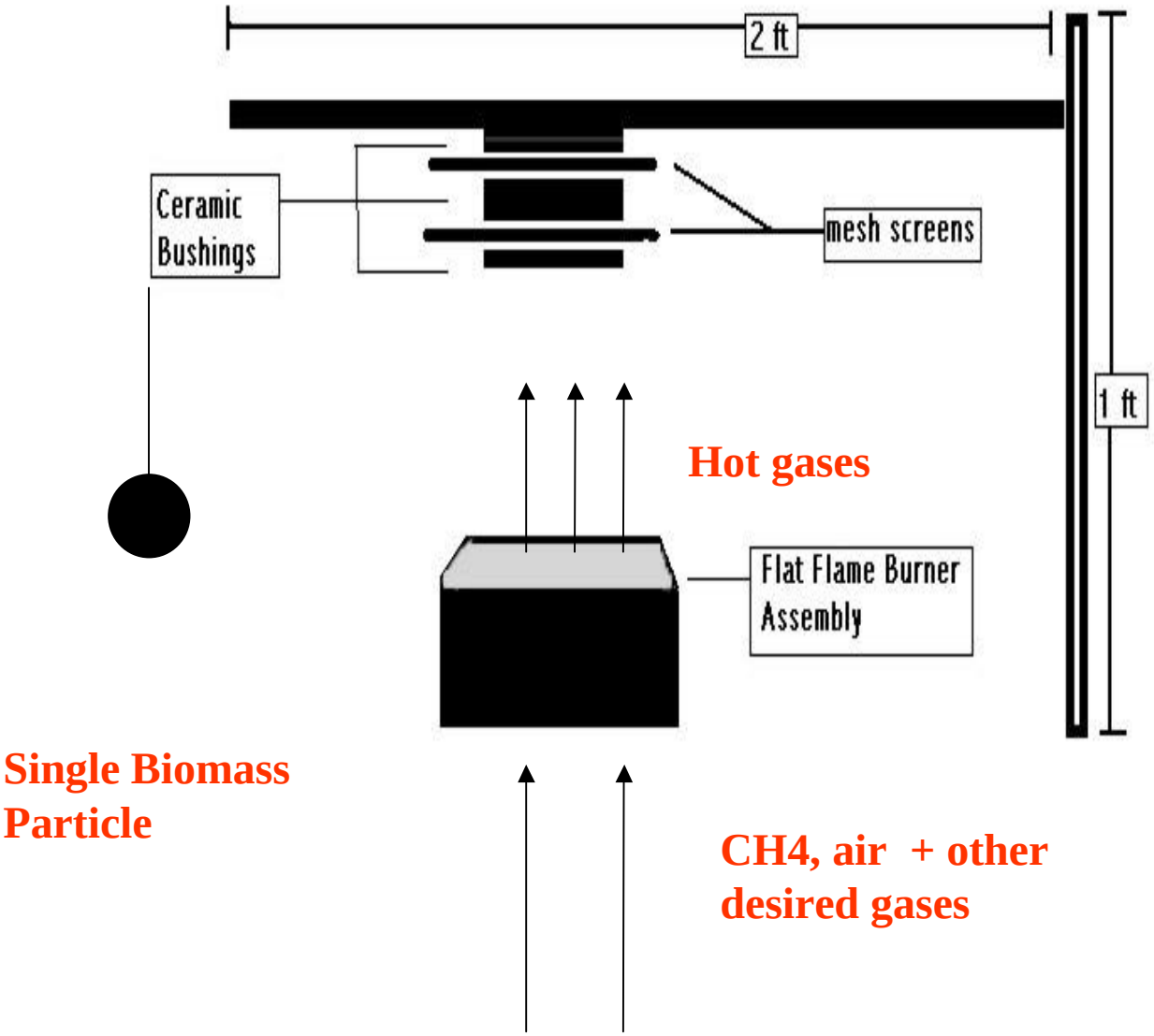
PROJECT PLANS or *TASKS*

- ***Tasks 1-3: Annamalai, (KA); Tasks 4: Sweeten (JS)and Mukhtar (SM)***
- ***Task 1. Fundamental experiments on fuel characterization and combustion studies(KA)***
- ***Task 2:Boiler burner experiments for cofiring of CFB and CLB fuels and reburn tests(KA)***
- ***Task3.Fixed Bed studies on CFB and CLB(KA)***
- ***Task 4. Numerical Modeling of pf fired and fixed bed burners (KA)***
- ***Task 5. Fuel Collection, Transportation and Economic analyses (JS+SM)***

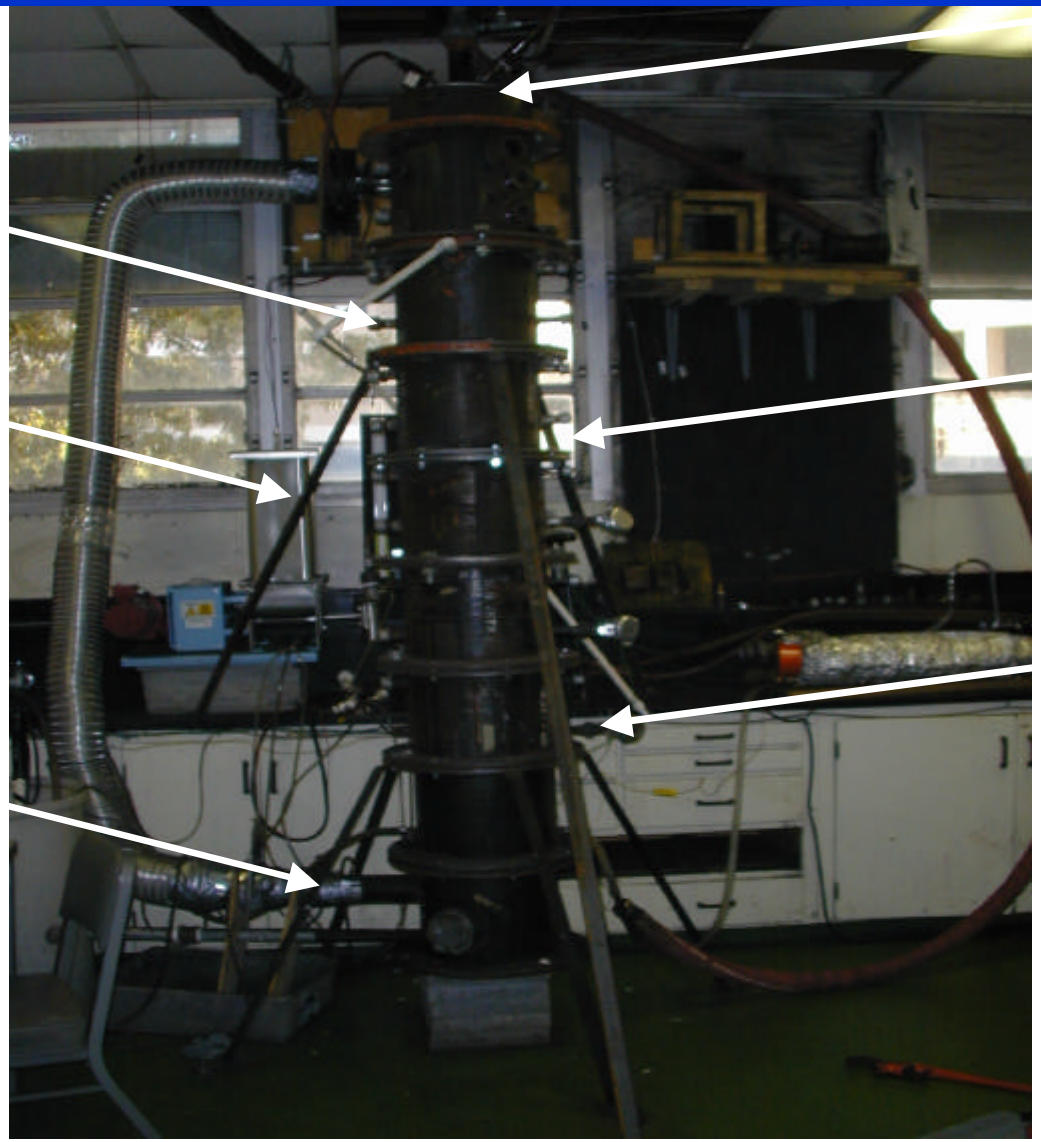
Available Facilities

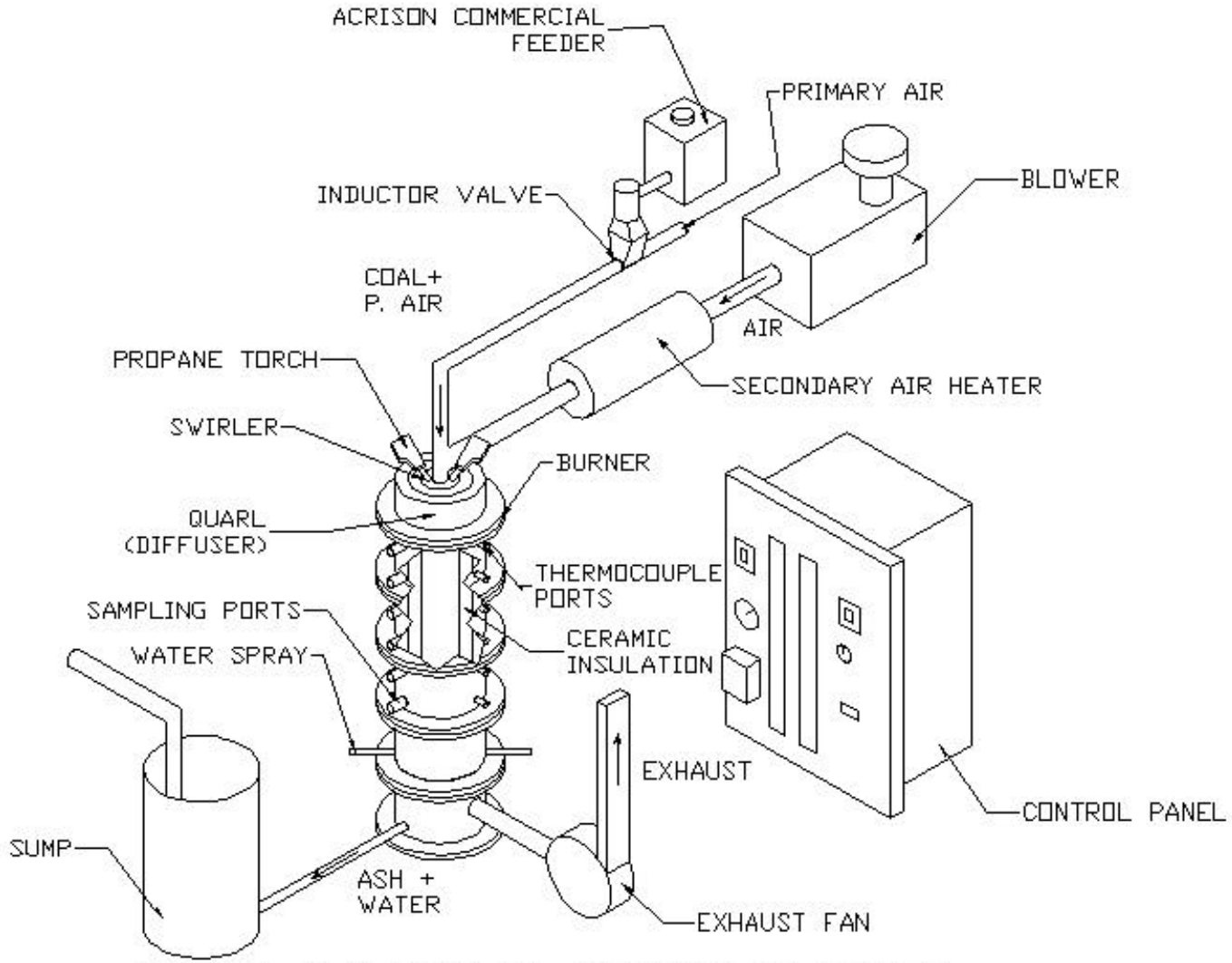
- **B(R)OILER BURNER for suspension firing**
- **Flat Flame Burner Facility for fundamental studies**
- **PCGC 2 (with 3 mix fractions) and PCGC 3 (being modified with 5 mix fractions)**
- **Economic Analysis Software developed for CFB**
- **Spreadsheet Software for gas analyses, N to NO Conversion etc and equilibrium temp calculations for any fuel**

TASK 1: FLAT FLAME BURNER FACILITY



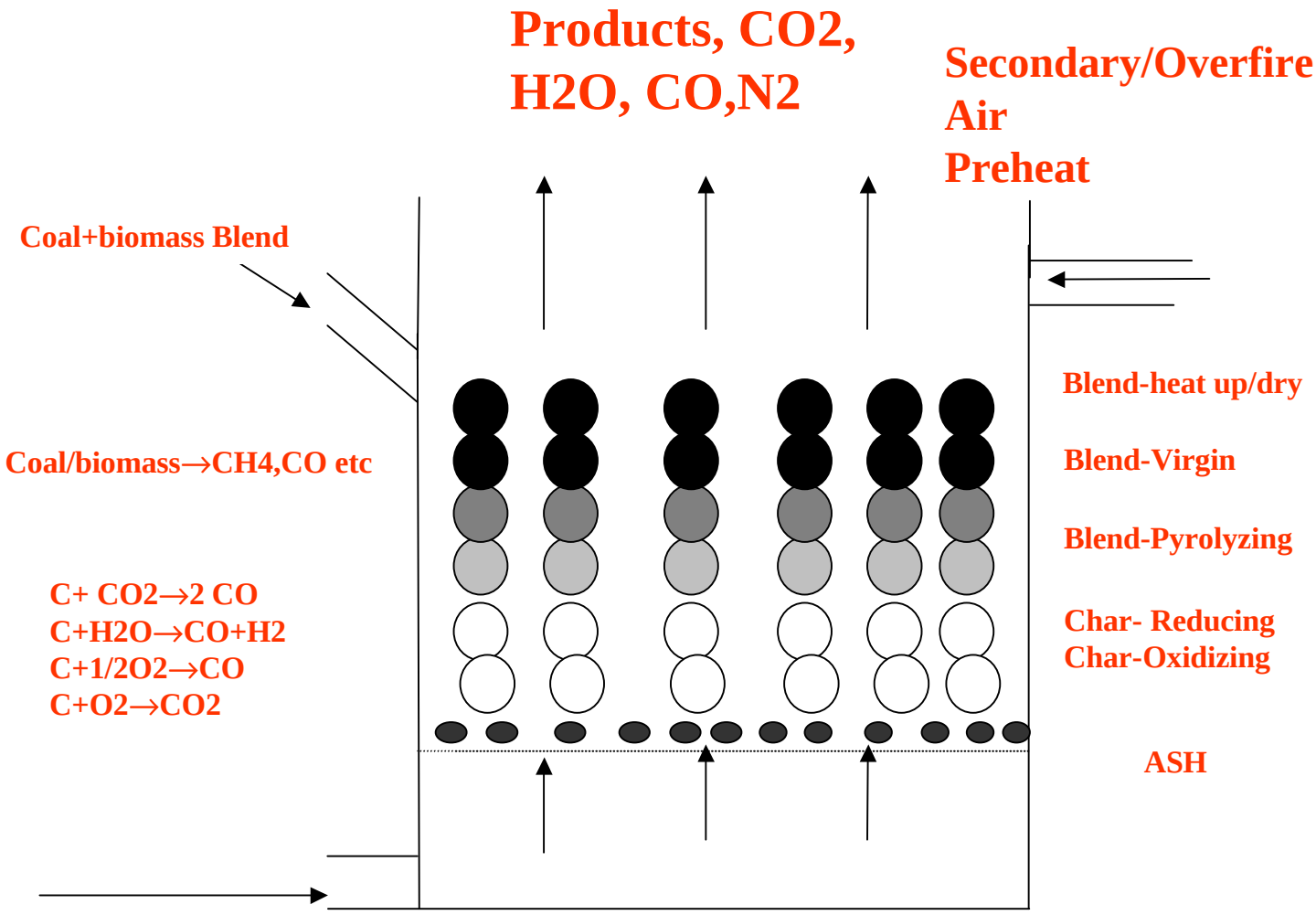
TASK 2:TAMU-30 kW BOILER BURNER FACILITY





TEXAS A&M BOILER BURNER FACILITY

Task 3: FACILITY TO BE FABRICATED



TASK 3: FIXED BED/STOKER GASIFIER/COMBUSTOR

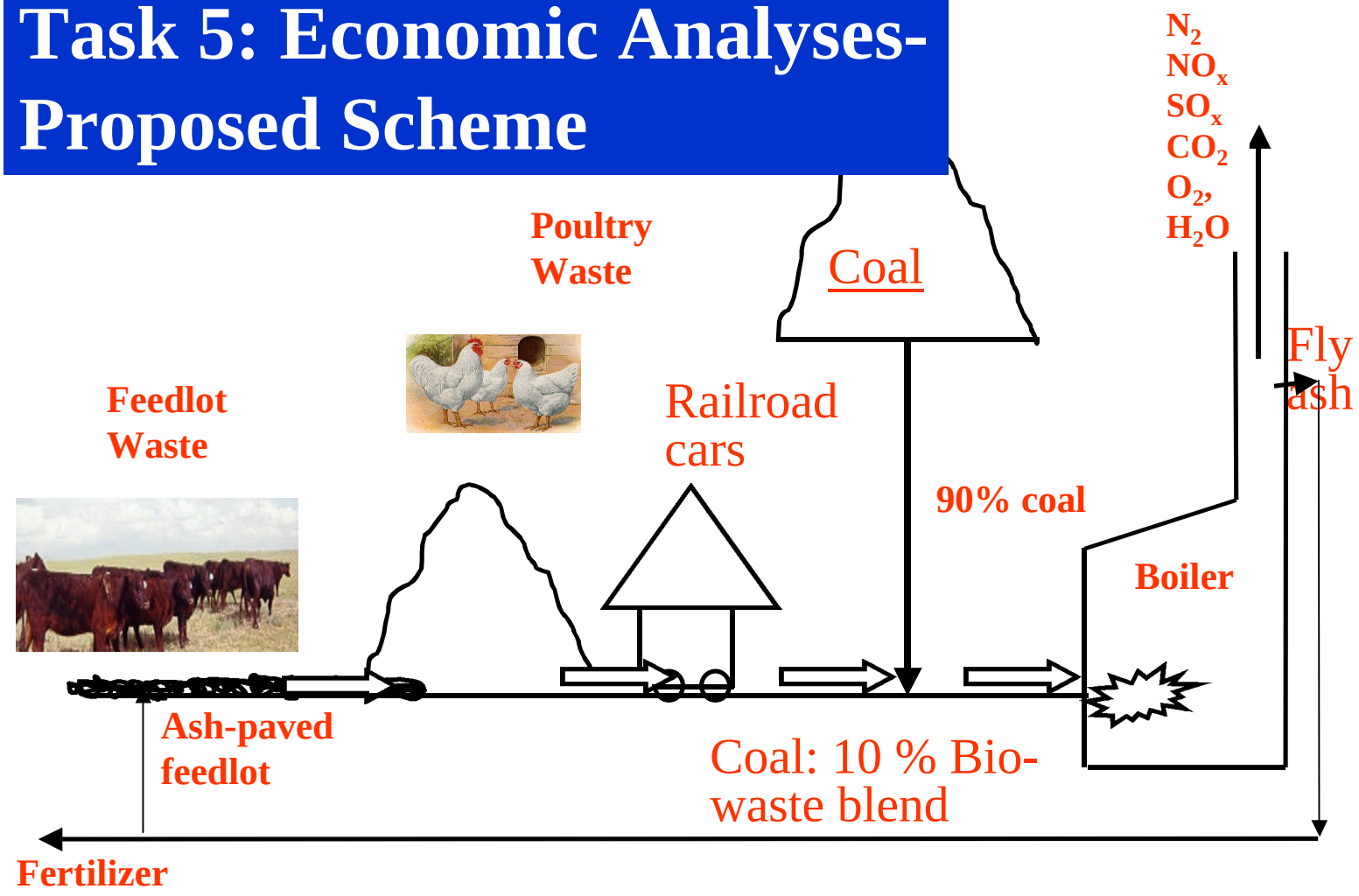
Task 4: Numerical Computation of Co-Firing of Pre-blended Pulverized Coal and Poultry Waste

Gengsheng Wei and Kalyan Annamalai

Department of Mechanical Engineering

Texas A&M University

Task 5: Economic Analyses- Proposed Scheme



PROGRESS

- **Task 1: Preliminary TGA Analyses performed on LB**
- **Task 4: Numerical Analysis performed with LB but with FB Kinetics**
- **Task 5: Economic Analyses: Preliminary study on Poultry Operations**

Broiler Barn

‘Cleaned Out’ Poultry Litter

Wet Cake near waterers`

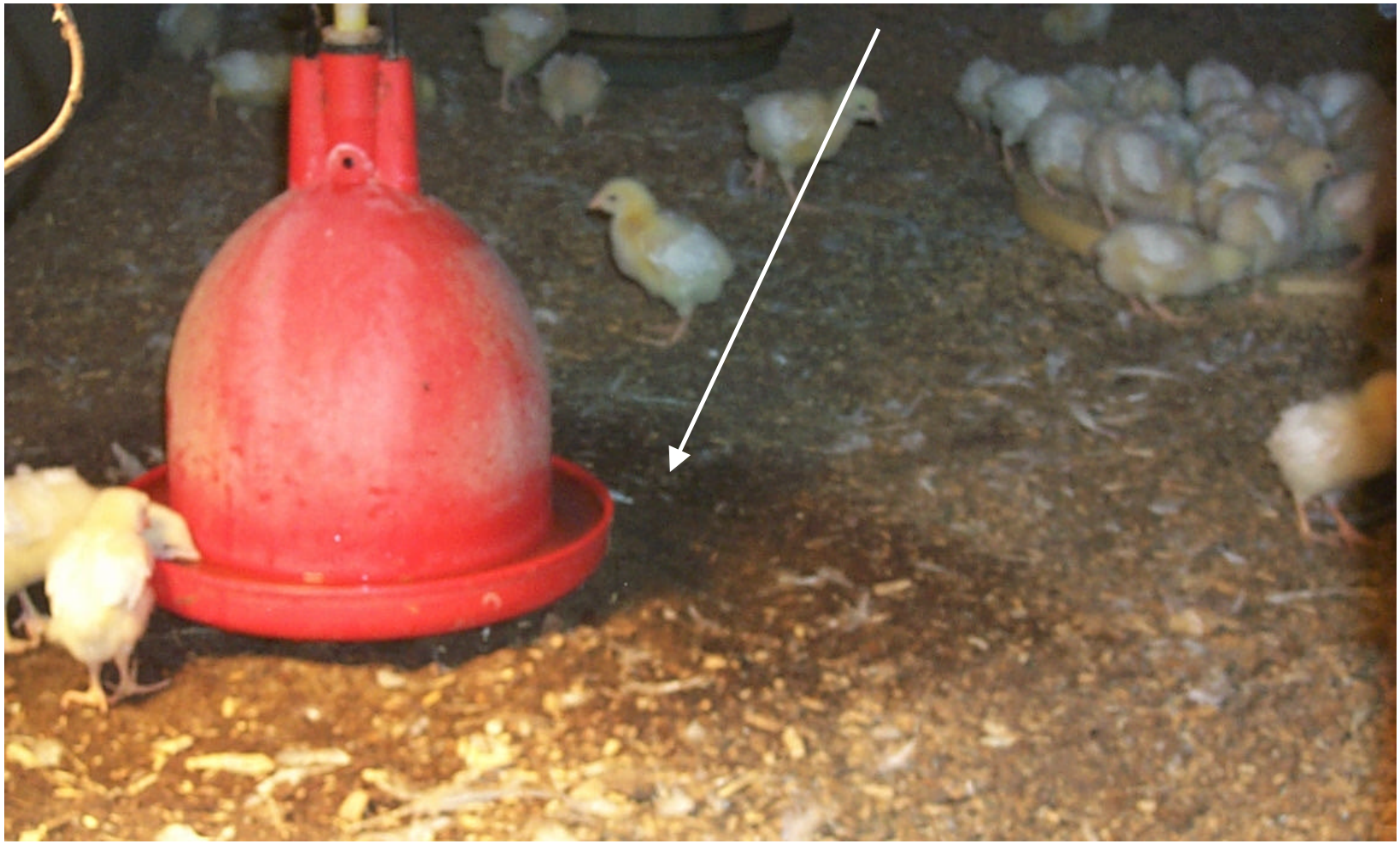
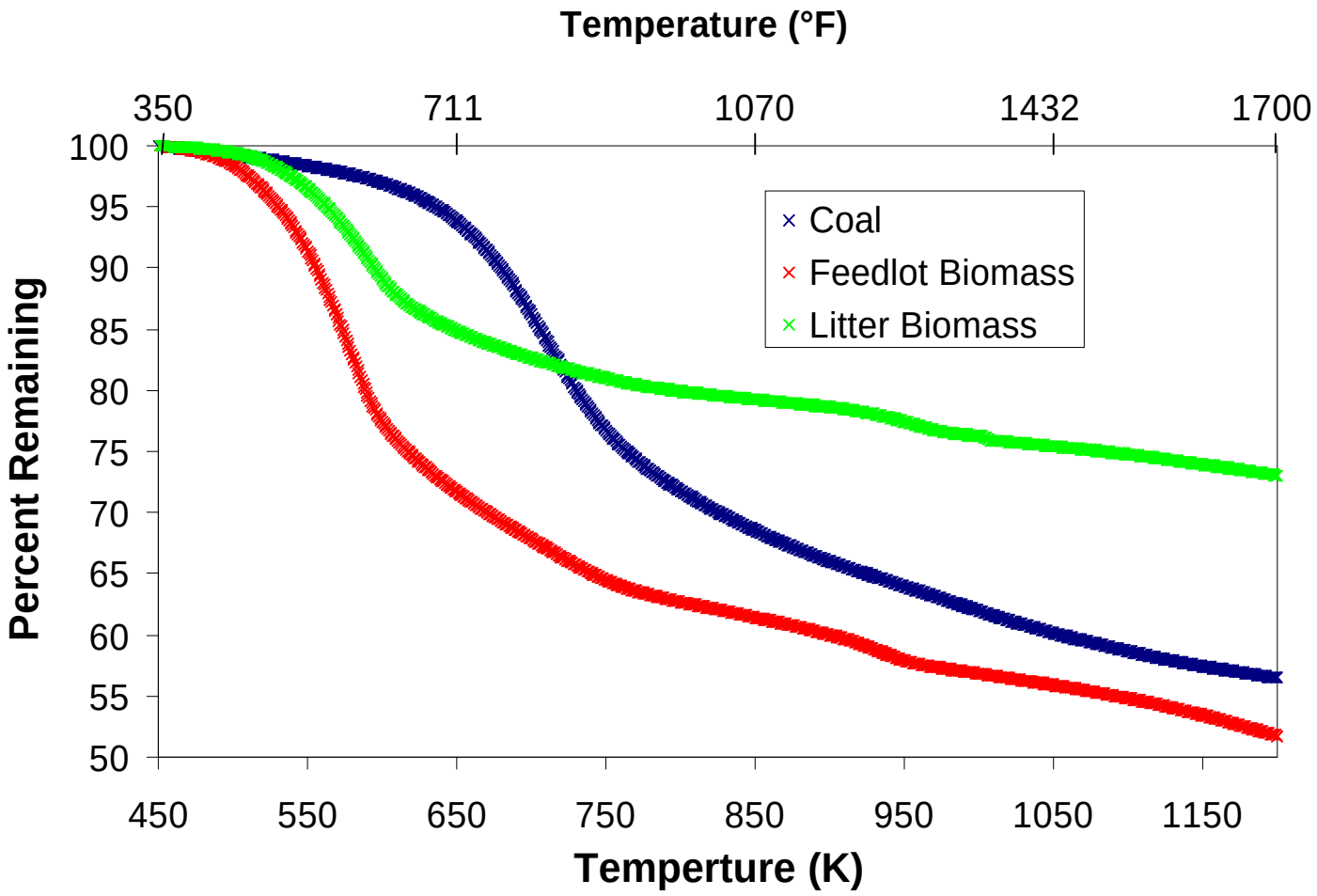


Table 2a: As Received Coal, Feedlot biomass (FB), Litter Biomass and blend Properties

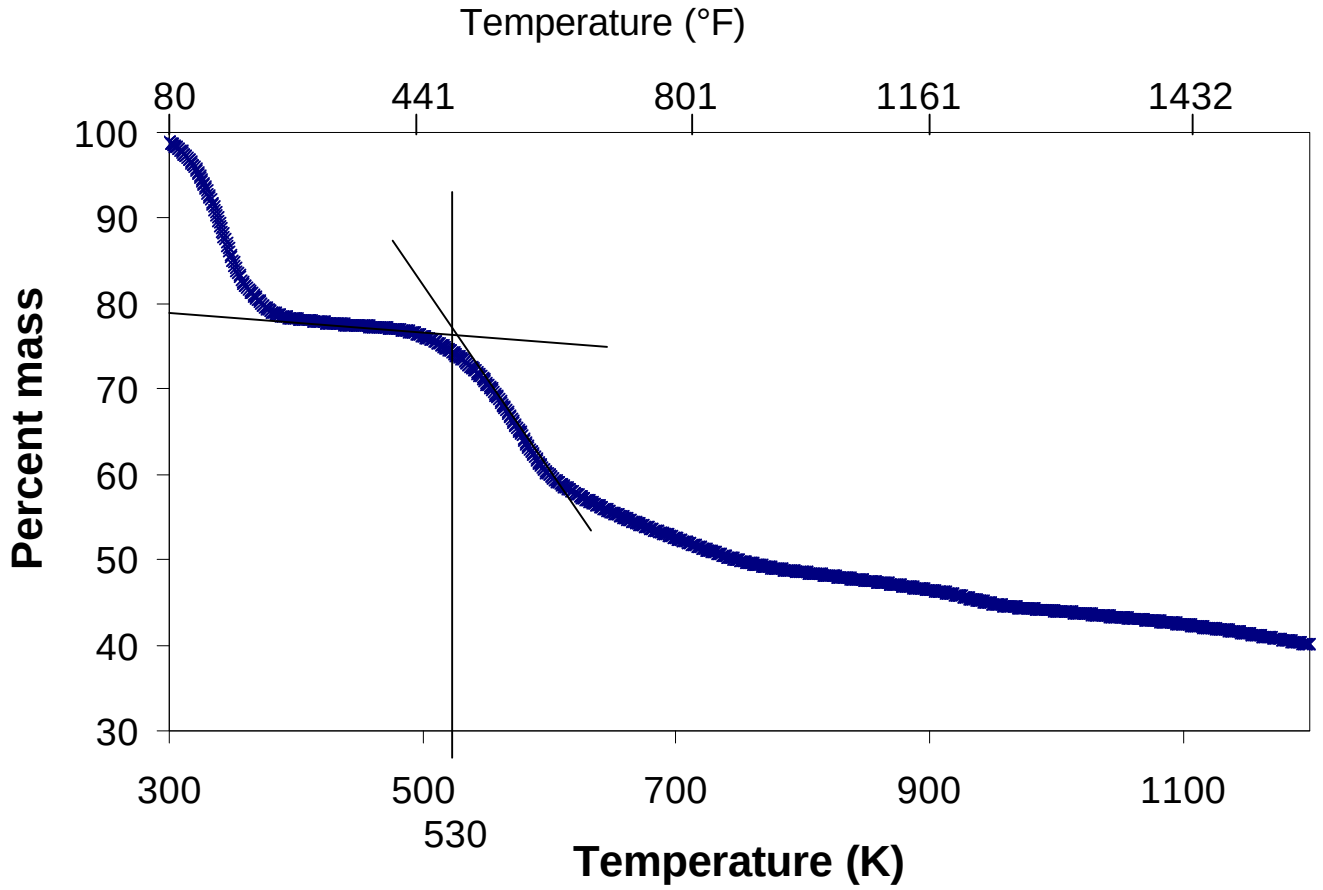
Parameter	Coal	FB	LB*	90:10 coal:FB
Dry Loss	22.805	6.79	29.75	21.2035
Ash	5.445	42.29	13.64	9.1295
C	54.065	23.895	29.2	51.048
O	13.075	20.26	19.68	13.7935
H	3.435	3.565	3.58	3.448
N	0.81	2.3	3.01	0.959
S	0.385	0.9	0.53	0.4365
Total	100.02	100		100.018
DAF Formulae	$CH_{0.755}O_{0.183}N_{0.0128}S_{0.0026}$	$CH_{1.774}O_{0.636}N_{0.0825}S_{0.0141}$	$CH_{1.46}O_{0.505}N_{0.0883}S_{0.00679}Cl_{0.0066}$	
`	21384 kJ/kg (9194 Btu/lb)	9561.5 kJ/kg (4111 Btu/lb)	11370 kJ/kg (4890)	20202 kJ/kg (9016 Btu/lb)
FC	37.25	40.4		37.565
VM	34.5	10.52		32.102

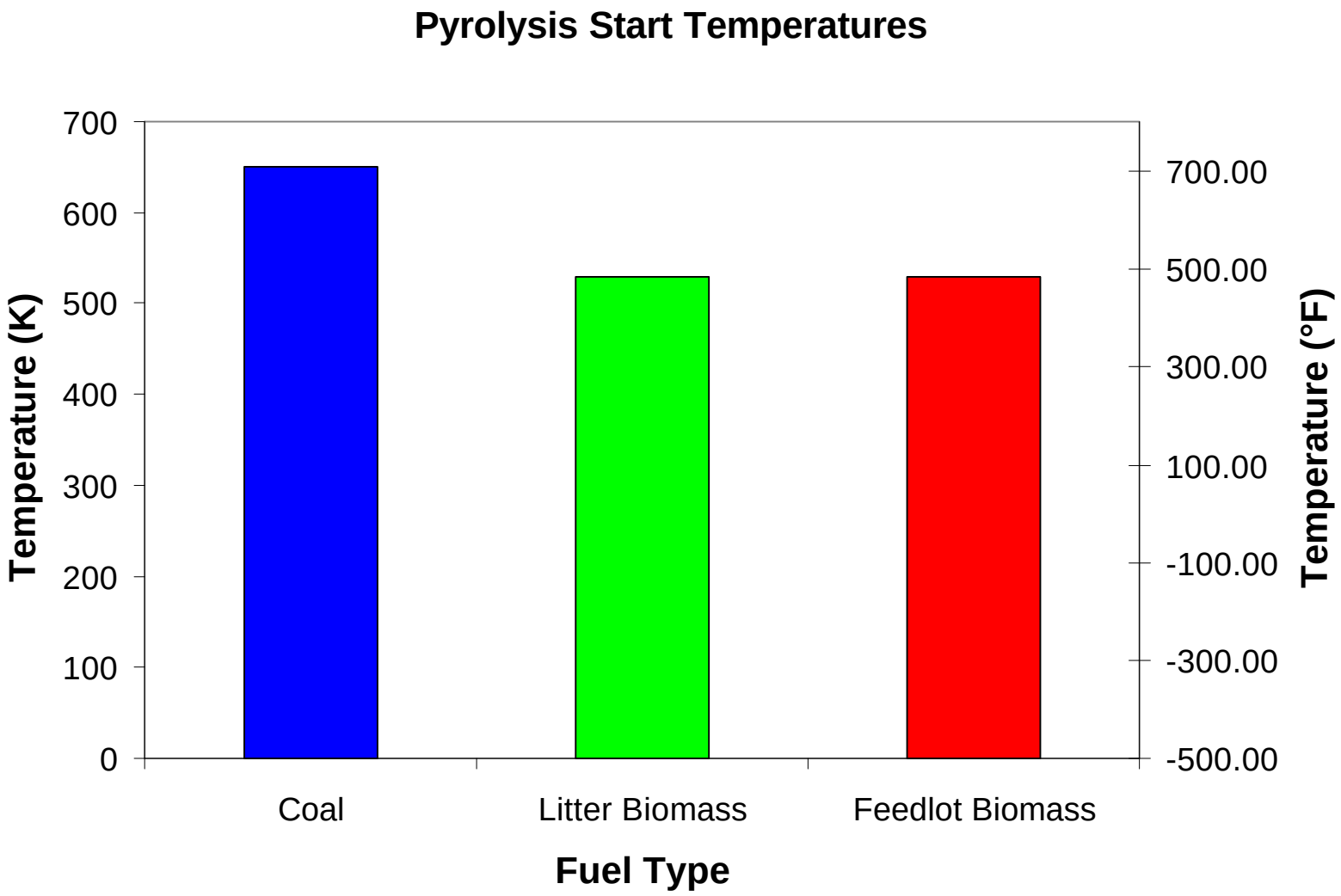
*** LB analyses from Tillman and Playsinski**

Task 1: TGA at 10°C/min; Dry % Basis



Estimation of Pyrolysis Start Temperatures: Feedlot Biomass TGA 10°C/min




Pyrolysis Start Temperatures
Temperature (K)
700
600
500
400
300
200
100
0
Temperature (°F)
700.00
500.00
300.00
100.00
-100.00
-300.00
-500.00
Coal
Litter Biomass
Feedlot Biomass
Fuel Type

Single Reaction model

	E kJ/kmol	ko (1/min)
Coal	6370	.0832
Feedlot Biomass	1550	.0496
Litter Biomass	5420	.0977

Parallel Reaction model

	E_m kJ/kmol	σ	ko (1/min)
Coal	232200	48100	1.002E15
Feedlot Biomass	201400	57400	1.002E15
Litter Biomass	209100	62200	1.002E15

Task 4: Numerical Modeling: B(r)oiler Burner

$$f = \frac{m_p}{m_p + m_s}$$

$$\eta_1 = \frac{m_c}{m_p + m_s + m_c}$$

$$\eta_2 = \frac{m_m}{m_p + m_s + m_c + m_m}$$

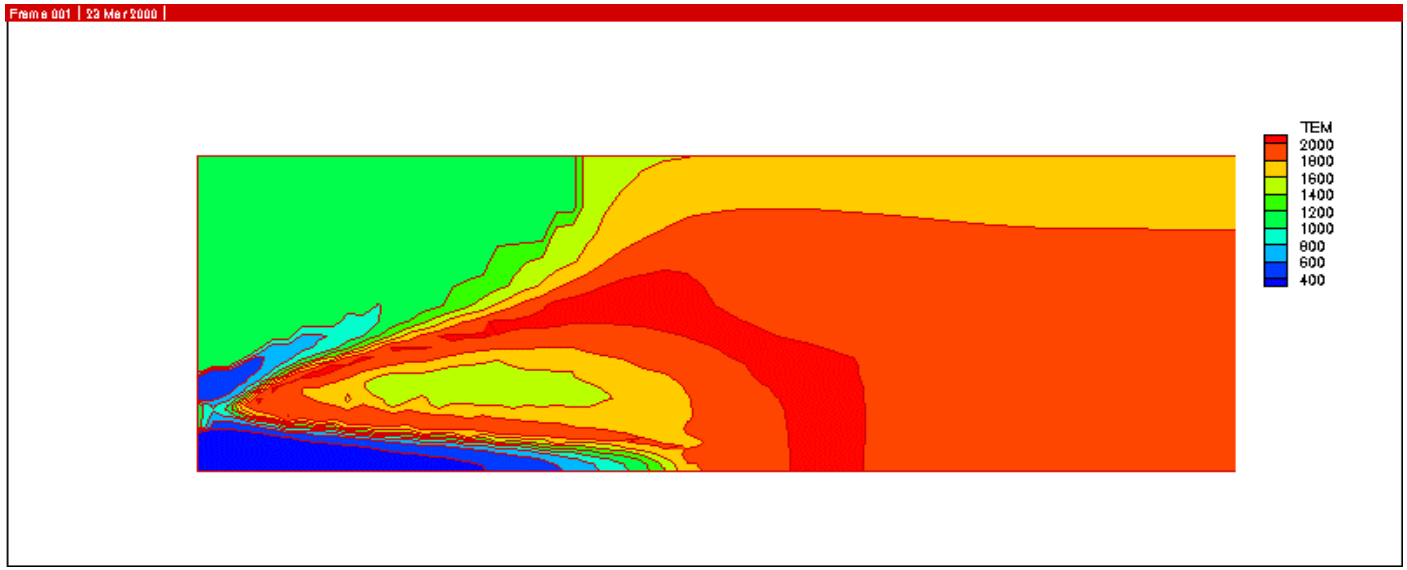
m_p = *mass of primary air*
m_s = *mass of secondary air*
m_c = *mass of coal off-gas*
m_m = *mass of manure off-gas*
f = *primary gas mixture fraction*
η_1 = *coal gas mixture fraction*
η_2 = *manure gas mixture fraction*

In fact, volatiles have different composition than the parent fuel.

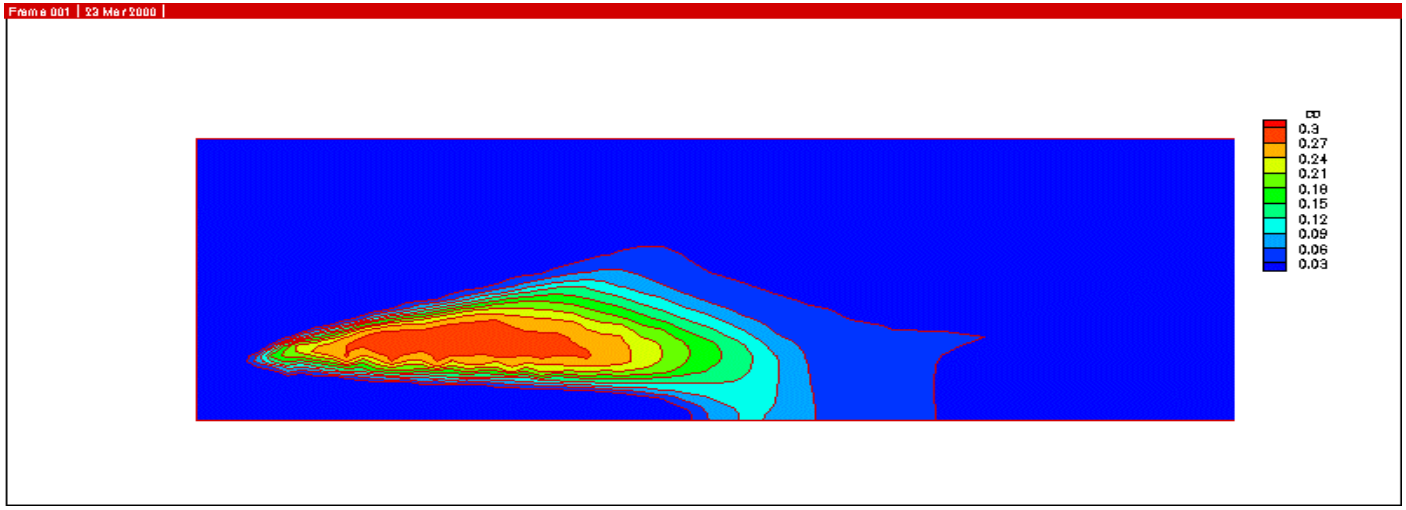
$CH_{0.8}$ (coal)= $0.4CH_2 + 0.6C$ $(H/C)_{coal} = 0.8$, $(H/C)_{vol} = 2.0$

$CH_{1.2}$ (manure) = $0.8CH_{1.5} + 0.6C$ $(H/C)_{man} = 1.2$, $(H/C)_{vol} = 1.5$

Temperature (K)



Molar Fraction of CO



EXPECTED ACCOMPLISHMENTS

Tasks 1-5

- Fundamental data on Fuel and TGA Analyses, Pyrolysis Kinetics of Coal, LB and FB, ignition and combustion characteristics
- Cofiring data Coal:FB and Coal:LB fuels
- Few Data on Fixed Bed Gasification/Combustion
- Numerical Modeling on Suspension Co-firing
- Economic Analyses and Feedback to industries including better waste management

TASKS 1 and 5/KA and SM

Proximate and Ultimate Analyses

- Feed Rations
- Broiler Manure
- Poultry Litter
- Litter without Manure
- Caked Litter and Composted Litter
- Heating Value

Task 2: Boiler Burner

- **Reactor has been modified for Reburn Tests with Coal:FB**
- **Once Finished, we will start with Coal:LB cofiring**

Task 3:Fixed Bed Gasification/Combustion Model: PROGRESS

- **Progress**
  - **Formulation and numerical method are established**
  - **Coding is done**
  - **Tests and debugging are going on**
- **Problems and difficulties in calculation**
  - **Ignition and then extinction occur for low inlet air temperature**
  - **Instability occurs**
    - **Relaxation introduced into variables to be solved and source terms, though.**

TASK-5/Mukhtar

Other Information

- **Sources of Phosphorus and Chlorine in Litter**
- **Flow Chart for Entire Poultry Operation**
- **Location of Power Plants in Texas, and Proximity to Broiler Operations**
- **Energy Consumption for Broiler Houses**

MILESTONES

SCHEDULE

Tentative Schedule of Tasks

Tasks	Months from the starting date								
	0	3	6	9	12	15	18	21	24
1	———	———	———	———	———				
2	———	———	———	———	———	———	———	———	
3		———	———	———	———	———	———	———	
4	———	———	———	———	———	———	———	———	———
5					———	———	———	———	———
Q		x	x	x	x	x	x	x	
Final Rep									x

Some Future Applications

- **Amarillo Power Plant**
  - **2100 MW (elec), 8 mill tons coal/year**
  - **Economic Analyses (spreadsheet software)**
    - **blend fire rate, ash, dollar, CO2 savings, Maximum collectable radius**
    - **ash disposal problem**
    - **pave feedlots, similar tech-L**
- **TAMU (38 MW):**
  - **elec, chilled and hot water, gas fired; nearby Sanderson farms**
- **Pilgrims Point (data to be collected)**
  - **Pilgrims Poultry Farms**